PROCESS FOR RECOGNITION OF TRACK MARKERS USING IMAGE DATA

The invention concerns a process according to the pre-characterizing portion of Patent Claim 1.

INS A1

Camera based systems for automatic vehicle tracking and for warning of unintentional deviations from the vehicle track or lane depend upon a reliable recognition of the vehicle lane boundaries. Typically, these boundaries are marked by means of continuous or interrupted lines. It is also known (for example: in the USA) to mark vehicle lane boundaries by a sequence of points (terrain points).

In US Patent 5,351,044, a process for recognition of vehicle lane boundaries is disclosed, which evaluates pixel-based image data. Therein, those image points of which the intensity or brightness significantly exceeds the intensity or brightness of the surrounding or ambient points are assigned to a border.

Further, a process is known which evaluates the correlation of the bordering image cells within the image data for detection of the vehicle lane boundaries. For this it is however necessary to transform the perspective camera data into non-perspective image data.

US Patents 5,517,412 and 4,868,752 show processes for detection of the vehicle lane boundaries, which are based on the segmentation of linear elements by means of line detectors ("edge detection") with subsequent Hough-transformation for reconstruction of the boundary. Similar technology is disclosed in US Patent 4,970,653, wherein here the segmentation of the line elements is supported by supplemental template matching.

In the process proposed in US Patent 6,091,833, the area in which linear detection is carried out is curtailed by the selection of areas which, transformed in the frequency space, exhibit a high intensity by their low frequency components.

INS A2

The task of the invention is to provide a new type of process according to the pre-characterizing portion of Patent Claim 1.

The task is solved by a process, which is described by the characteristic features of Patent Claim 1. Advantageous embodiments and further developments of the invention are set forth in the dependent claims and described on the basis of illustrative embodiments and figures.

Figure 1 shows an image section **10** with point-shaped vehicle lane markings **11** and selected areas (ROI) **12**.

Figure 2 shows a flow diagram with respect to the recognition of the point-shaped vehicle lane markings 11.

Figure 3 shows a flow diagram concerning the binarization or digitization of the image point (pixel) which is associated with the vehicle lane boundary 11.

Figure 4 shows an example of a gray-scale or tonal value processing of image data, wherein the regions evaluated by the matched-filter are extracted.

INS A3

In the inventive process, the morphological characteristics of point-shaped vehicle lane markings are considered or evaluated on the basis of *a priori* or common knowledge. Therein, beginning with a starting image, a multi-step search is made for point-shaped vehicle lane markings ("Bot Dot Markings").

In Figure 1 there is shown a preferred manner, in which for minimizing the processing complexity, and, at the same time, for reduction the false alarm likelihood, areas (ROI) **12** to be processed are separated out from the totality of the image data **10**. This occurs beginning with *a priori* knowledge with the goal, to select areas **12**, which with high probability contain vehicle lane markings, so called ROI (regions of interest). Herein the positioning of the ROI occurs in effective manner on the basis of the known camera geometry (height, tilt angle,. . .) as well as on the basis of other perimeters such as for example the geometry of the vehicle track, the dimensions of the vehicle lane markings or the vehicle position within the vehicle lane. Herein it is generally assumed, that the vehicle is situated between left and right markings, and the vehicle lane breadth meets certain standards.

In Figure 2 there is shown, as an example, the individual steps of the inventive image data processing beginning from camera image **10**, which still contains the entire image information, up to the extraction of the coordinates for individual elements of the vehicle lane marking, which in general correspond to the coordinates of marking points.

In a first step **21** areas (ROI) **12** are separated out from the entirety of the image data **10** to be processed. For this, in the initialization of the ROI **12** in the framework of the inventive process model parameters are varied so long until vehicle lane markings are found. Therein, as model parameters there are taken into consideration for example information such as the breadth of the vehicle lane, the positioning or orientation of the camera with respect to the center of the vehicle lane or the yaw angle of the vehicle. In the later course of the process, for

repositioning of already initialized ROI **12**, parameter predictions from a vehicle-street-model are drawn upon on the principle of a prediction of an evaluation process for parameter determination. For this, evaluation processes are advantageous which are based upon a Kalman-filter. In the repositioning of the ROI **12**, it is in advantageous manner controlled by the variation of the result value of the prediction of the evaluation process for parameter determination, wherein the width is adapted proportionally to the size of the variance of the results. It is likewise advantageous to limit the ROI **12** vertically on the basis of a minimal and a maximal distance in the street plane. This is particularly useful when the inventive process is employed at night. Herein in advantageous manner the vertical limitation of the ROI **12** is determined by the range of the maximal illumination (high beam, low beam). It is conceivable that the regulation is controlled by the number of the image points expected to be associated with a vehicle lane marking, wherein this regulation is then considered as optimal when the number of the image or measuring points to be expected is maintained constant over all distance ranges.

According to the number of suitable ROI **12**, a matched-filter is employed in process step **22**, in order to better extract the image points (pixels) associated with a vehicle lane marking from the background. Herein the matched-filter is advantageously adapted to the shape and size of the vehicle lane marking and/or the statistics of the background being searched.

In particularly advantageous manner, the matched filter is so arranged that in the framework of its application in the environment of the position being examined, the average gray scale or tone value (hereafter gray value) of the background is measured, and that on the presentation of an image point, which

is potentially to be associated with a vehicle lane marking, is confined on the basis of a comparison between background noise, the average gray value in the environment, and the gray value of the position to be searched. In general, for this the filter is implemented in separated geometry or model-type, in which the x-y components are presented separately. It has however been found, that for location or determination of point-shaped vehicle lane markings in the most cases, the processing complexity can be reduced, when in the evaluation of the matched filter only the x-components are considered. For this, the average value and the standard deviation right and left of a position to be examined are measured. If the gray value exceeds the average value of the intensity of the background at more than the comparative threshold determined from the white noise of the background and threshold determination, the position is marked as potentially belonging to a vehicle lane marking.

Figure 4 shows, as an example, the gray value curve **40** over an image cell to be evaluated within the image data or, as the case may be, the ROI, wherein in this example only the x components are taken into consideration. For evaluation of the image point **41** on the position x_0 of the image cell, the intensity thereof as well as the statistical information of two same size areas S1 and S2, which are situated at a distance d of xO therefrom, are evaluated. The distance d is preferably selected to be a value, which is predicated or predicted by the evaluation process for parameter determination in process step **21** (Fig. 2) as the to be expected width of an element of the vehicle lane marking. It is, on the other hand, however also possible to assign the distance d in the framework of the inventive process a fixed value (for example an expected value) and to so leave it. The size of the area or range or field S1 and S2 is in advantageous manner selected to be identical, wherein their measurements, if possible, should not be larger than the predicated or predicted

value of an element of the vehicle lane marking. If this predicted value is however so small that no useful statistical evaluation of the values contained in S1 or, as the case may be, S2 any longer appears possible, then the areas or ranges S1 or, as the case may be, S2 can also be selected to be larger. In practice, in the predication of the width of the elements of the vehicle lane markings of two pixels, the selection of five pixels as the width of areas S1 and S2 has been found to be effective.

From the values within areas or ranges S1 or S2, the average values A1 or, as the case may be, A2 and the standard deviation $\sigma 1$ or, as the case may be, $\sigma 2$ is calculated. The standard deviation $\sigma 1$ or, as the case may be, $\sigma 2$ is subsequently employed for calculation of the threshold values T1 or, as the case may be, T2. Therein, it is conceivable, in a first step or statement or set-up to select the threshold values according to the three-fold of the respective standard deviations, thus to select $T1 = 3 * \sigma 1$ and $T2 = 3 * \sigma 2$. In particularly advantageous manner, the thus generated threshold values are corrected by means of a threshold value controller or regulator **25** described in greater detail in the following. After the determination of the threshold values T1 or, as the case may be, T2 and their subsequent correction, the support points for the comparison threshold **42** is calculated by addition of T1 and A1 or, as the case may be, T2 and A2. Herein the center of the area S1 and S2 is advantageously selected as the x-position of the support point. Subsequently, the value **41** at the position x_0 can now be compared with the value of the comparison threshold **42** and the comparison result can in inventive manner be drawn upon for identification of elements of the vehicle lane marking.

The image point (pixel) identified and extracted by the matched-filter, which is associated with vehicle lane markings, are

digitized (conversion to binary) in processing steps **23**, **24**, and **25** and collected into groups. In the digitization, the intensity of the individual pixels are compared with a threshold value and then the compared pixels are only drawn upon for a further processing when their intensity exceeds this threshold value. In Figure 3, the inventive process step for digitization is elucidated on the basis of a flow diagram. Herein the threshold value T1 and T2 is determined from the background noise in advantageous manner by means of a threshold value controller **25**. For the determination thereof, it is useful when the threshold value controller draws upon *a priori* knowledge about the expected surface **35** occupied by the vehicle lane marking, which correlates directly with the expected number of the vehicle lane marking associated image points (pixels). In this manner, the threshold value controller **25** can be so set up or arranged, that it aims in directed manner to relate the number in the ROI **12** extracted image points as precisely as possible to the expected value thereof. After the extraction of image points potentially belonging to a vehicle lane marking and their subsequent digitization **33**, these are collected in process step **24** for a further processing (for example within **35**) for marking objects (pixel groups).

After the generation of marking objects, these can be examined in process step **27** with respect to their correspondence with the known morphological characteristics of the vehicle lane markings. Herein in advantageous manner for example the size of the marking objects, their roundness, the individual image points (pixels), or the number of free spaces within the marking objects (compactness, clustering) are evaluated, as to whether they can satisfy the criteria of the morphological characteristics of the vehicle lane markings on the basis of *a priori* knowledge. Based

upon this determination, each pixel group, which satisfies the criteria of a vehicle lane marking, is considered to be an actual marking object and is characterized by the image coordinates. For this, in advantageous manner, the coordinates of the center of gravity of the marking image associated pixel group can be selected as the characterizing image coordinates.

After successful characterization of the marking object, the image coordinates can be employed, using curve regression, in order to describe the boundaries of the own vehicle track or in certain cases, the course of the vehicle track as well as the own position with respect to the the vehicle lane center. It is then particularly useful to supply this description to the inventive evaluation process for parameter determination (for example a Kalman-filter) for repositioning of the ROI within the image data.

The invention process is, of course, not limited to the recognition of dot-shaped vehicle lane markers. It is also possible therewith, for example, to recognize continuous linear vehicle lane markings even when these have been strongly degraded by changes or wear.